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MATHEMATICAL MODELING AND RELATED PROCESSES IN THE AREA  
OF DIVING PHYSIOLOGY(U) AUTOMATION COUNSELORS INC  
FREDERICK MD 30 APR 83 N00014-80-C-0421

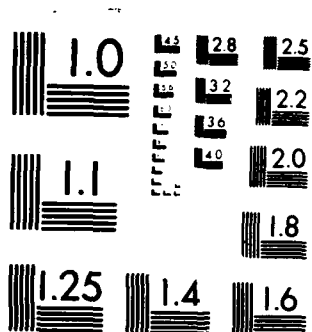
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FINAL REPORT  
(Contents Unclassified)  
CONTRACT #N00014-80-C-0421

OFFICE OF NAVAL RESEARCH

Mathematical Modeling  
and Related Processes  
in the Area of  
Diving Physiology

AD A128786

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## CONTRACT ACCOMPLISHMENTS

Contract #N00014-80-C-0421

Automation Counselors, Inc. (ACI), working at the Naval Medical Research Institute's Hyperbaric Medicine Program Center was directed to address three functional areas including:

- Support of Individual Research Projects - Work done for individual research projects involved a full range of effort. New projects required a lot of design work, e.g., deciding on experimental protocol so that data gathering could be automated, feasibility of automation, degree of automation, etc. Ongoing projects required new modifications in existing software and new methods of analyzing the data.
- Support for Information Management by Various Groups - ACI identified the vast amount of effort expended by various groups in record-keeping and decided to provide simple data base management features in the system in order that various groups could automate their record-keeping.
- Support of Generalized Nature for All Computer Users - ACI identified the various needs of general nature by all users and provided solutions. The effort involved generalized statistical analysis methods, graphic illustration, data file management, and bibliographic reference management.

The accomplishments by Automation Counselors, Inc., in each of these areas are discussed in this report.



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## SUPPORT OF INDIVIDUAL RESEARCH PROJECTS

- Study of HPNS - Tremor Response in Laboratory Animals -  
The investigator had a device that produced an electrical signal proportional to the physical tremor and had started recording the experimental tremor data on analog tapes. Analysis of existing data on analog tapes and future experimental data was required. We determined that several different methods of analyses were needed for testing to obtain the maximum information from the data. Therefore, the original signal needed to be saved. Considering the amount of on-line storage space required for digitally storing the signal, it was decided that analog tape would be the best means to store existing data as well as that from future experiments. This also reduced the number of programs requiring maintenance.

We took advantage of the fast playback features of the tape recorders, thus cutting down on the amount of time required to analyse the signal at 64 samples/second of real-time (adjusting the sampling rate for fast playback) and screened it for the presence of the tremor. If a tremor exists, the signal "is converted" into frequency domain by taking Fast Fourier Transform of the data and eventually calculating the average power spectrum.

Different methods for screening the data for existence of tremor were tried. Overall analysis of the "average power spectra" at various time slices during an experiment and a cross experiment are being discussed.

- Estimation of Decompression Risk Due to Bubble Formation for Given Dive Profiles Using Maximum Likelihood Technique - This project involved computing the probability of succumbing to decompression sickness for a given dive profile. This was achieved by integrating a risk function over the period of dive, the risk being the function of several factors such as ambient partial pressures of various gases inhaled, arterial partial pressures, and tissue partial pressures. Various factors were considered in setting up the mathematical model including:
  - Determine the generalized input data format for the dive profiles since data from outside sources was also to be used.
  - Allow for future needs when calculating the risk function such as temperature, work/no work conditions, etc.

- Consider the computational time involved and implement that factor for maximizing speed.

Since the model required large numbers of data points to work well the investigator decided to acquire data from well documented dives from other facilities. DCIEM, Toronto Canada, has a large, well organized data base on dive outcomes. There were two major problems in acquiring Canadian data. First, the physical transfer of data from Canada to NMRI presented a problem since the Canadian data base was under a UNIX operating system and the dive records had a vast amount of information which had to be screened out. An ACI consultant collaborated with the Canadians to determine the format for the transfer. The second problem was to convert the data from the transfer format into the generalized input format for the model. This involved scanning the ASCII transfer file, identifying the useful information, displaying the time pressure curve on a graphics screen, fitting the curve to a series of step functions and saving the step functions in a data file with the proper format. Goodness of fit had to be evaluated before accepting the fitting algorithm.

- Measurement of Tissue Exchange Rates for Various Gases Using Positron Detection Cameras - The investigator used the Linear Accelerator and Positron Detection facilities at Lawrence Livermore Laboratories (LLL) to perform the experiments. The data was gathered by a PDP-15 computer and transferred to their CDC computer facility. Due to the binary nature of the data and incompatibility on the computers involved, the data transfer itself was a tedious task. Once the data was transferred onto the NMRI computer the following steps had to be taken to process the volume of information involved.
  - Since each experiment consisted of 200,000 to 500,000 data points, thorough data checking was necessary. This was done (and still is being done) by spot checking and comparing with original data at LLL; obtaining various dumps and profiles of the data; and displaying portions of the data to confirm the locations of radioactive sources.

- The investigator needed to "look" at the data to get the proper perspective on how to analyse it. Various programs were set up to display X-Y portions across time and time slices across X-Y portions. Here again, the volume of the data became a major problem in manipulating it.
  
- Study of the Pulmonary System as an Electrical Network - ACI provided the understanding of the electrical network and how the phase angle between the current vector (flow) and the voltage vector (pressure difference) depends upon the impedance (airway resistance and lung compliance), so that the investigator could model the pulmonary system as an electrical network. A series of network models were set up to study various aspects of the lung function.
  
- Blood Flow Rates to Cerebral Tissue Under Normal and Ischemic Conditions and the Effect of Various Drugs on the Blood Flow - ACI has been providing support to this project under an earlier contract. The investigator was interested in correlating the flow-rate data with other measurements, e.g., heart rate, blood pressures, cerebral edema, hematocrit, etc. Major design changes had to be made to the original data structure to incorporate the new information. The analysis programs were modified to look at the new data.
  
- Effect of Carbon Dioxide in Regulating Respiration at Normal and Increased Atmospheric Pressure - Experiments were performed to determine respiratory response to raised inspired concentration of carbon dioxide under dry and immersed conditions, and normal and increased pressures. Observations included inspiratory flows and pressures, pressures 100 m sec after airway occlusion, etc. Since most of the data had already been collected we could not automate data acquisition. Also, most of the data was gathered on strip chart recorders and therefore had to be manually digitized. The programs for digitization had to be constructed to detect operator errors and to recover from them. Since methods of analysing the data were not fully determined, various techniques were tried.

- Study of Pulmonary Oxygen Toxicity - NMRI is interested in an easily measurable index of the development of adverse effects from breathing high concentrations of oxygen. ACI studied the literature and recommended that lung metabolic function in animals breathing one-hundred percent  $O_2$  should be measured. The metabolic function could be monitored by measurement of angiotensin I in dogs that are catheterized for repeated blood withdrawal. Chronic catheterization techniques, (radioimmunoassay for angiotensin) should be further studied.
- Effect of Decompression on Lung Function - Human subjects were put through a pressurized air dive of 285 feet for ten minutes. Volume and various pressures were monitored before and after the data. The data was acquired on an HP-9825 computer. The analysis involved transferring the data onto PDP 11/70 and calculating various indices of lung mechanism such as changes in pulmonary resistance, compliance, etc. Since the exact method of analysis was initially undetermined, various methods were tried. The data was graphically displayed so that the investigator could choose the portions of data using cursors. Various methods of data extraction and editing were necessary to make the analysis possible.

Selected portions of data were used to test various hypothesis. Most of the analysis methods turned out to be useless due to the tremendous variance in the data.

- Air Embolism Study - Under a previous contract ACI developed a real-time data acquisition and monitoring package for an air-embolism project.

DP/DT (first derivative of cardiac pressure) was being monitored and saved in terms of arbitrary A/D units. It was found that DP/DT can be calibrated by using a sine wave of known frequency and amplitude. The programs were modified to show the actual values of DP/DT signal.



## INFORMATION MANAGEMENT SUPPORT

- A record-keeping system of maintenance requirements for laboratory equipment in terms of maintenance type, frequency and last maintenance date was set up. At the user's request, the system provides information on the equipment which needs maintenance by a certain date. The system allows for entry of new items, maintenance updates, and a report of file contents. The system was expanded, after initial use, to hold equipment for which no maintenance is desired.
- The Diving Chamber Maintenance Schedule (DMS) was put under a data base.
- The PMS system generates weekly maintenance schedule, checks to see if tasks were completed in a timely manner, and flags critical areas from safety point of view.
- A data base was designed for personnel administration of HMPC so that the information could be easily accessed.
- Purchasing records for the HMPC were computerized in order that chits can be tracked through the completion phase and reports for various departments within the program center can be generated.
- Automated spare parts inventory and equipment list for the chamber complex was installed.
- A data base for information regarding pressurized gas bottles was set up so that the Lab needs for various gas mixtures can be met with ease.
- An inventory system of the Lab animals was automated to keep track of all Lab animals, ordering and billing.

## SUPPORT OF GENERALIZED NATURE

- A general purpose statistical analysis program was set up to analyse any data. The following analysis can be done: frequency distribution histogram, paired T-test, two sample T-tests, linear regression and correlation, and Wilcoxon rank sum tests. The data can be entered on-line via a user's terminal or can be accessed from a data file. Accepted data file format is similar to SAS or BMDP data formats or it can be a single column of numbers. The program can screen the data for missing data points and can also deal with a sub-set of the entire data file. The program can be used simply as a calculator to get mean, standard deviation and standard error of a group of data points entered on the user's keyboard.
- A one-way analysis of variance programs was written for general usage.
- A series of file management programs were set up to manipulate the data files so that various analysis and display programs can be used once data is entered into a file.
- An easily used root-finder program for single variable non-linear equations was set up for general usage.
- A Tektronics graphics package EZGRAF was modified to provide a more dynamic buffer space, more symbols and line types. The increased buffer space allows the user to create elaborate illustrations without running out of memory space. The original package could be used only for very simplistic graphs.
- A graphics subroutine package from Lawrence Livermore Laboratory was installed so that 3-dimensional graphs can be displayed on the Tektronix 4014 terminals.
- A general purpose program was written to create graphs on a Versatec printer plotter. This program facilitates users in obtaining graphical output without having a graphics terminal at their disposal.

- A previously written, non-linear function fitting package, NLFIT, was modified to automatically give graphical output of the raw data and the fitted function.
- A VT-11 graphics terminal was re-configured as a GT-40 subsystem in a host satellite set up. This upgrade off-loaded the graphic display onto a satellite computer (PDP 11/04), thus releasing the main processor for other tasks.

Existing software using the VT-11 was converted for the new configuration.

- A generalized procedure for the extraction of references from a bibliographic file was set up. The procedure allows the user to search for all references containing user specified text strings and create a new sub-list.

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